Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 SEP 2003	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Modularized Unmanned Vehicle Packages for the Littoral Combat Ship Mine Countermeasures Missions	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Office of Naval Research 800 North Quincy St. Arlington, VA 22217**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002146. Oceans 2003 MTS/IEEE Conference, held in San Diego, California on September 22-26, 2003. U.S. Government or Federal Purpose Rights License, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**3**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Modularized Unmanned Vehicle Packages for the Littoral Combat Ship Mine Countermeasures Missions

Robert T. Schnoor

Office of Naval Research
800 North Quincy St.
Arlington, VA 22217
schnoor@onr.navy.mil

Abstract- The planned acquisition of a leased High Speed Vehicle (HSV) for Mine Countermeasures (MCM) and Littoral Combat Ship (LCS) experimentation provides a significant opportunity to examine and accelerate unmanned systems for mine countermeasures. The Office of Naval Research (ONR) S&T investments are developing containerized mission packages (to include inexpensive AUVs for minehunting, and Unmanned Surface Vehicles (USV) for minesweeping) for demonstration on HSV-2 *SWIFT*. This builds on the rapid advance of AUV technologies and capabilities demonstrated on HSV-X1 *JOINT VENTURE* during Fleet Battle Experiment- JULIET. ONR is currently working with the Coastal Systems Station (CSS), Panama City, Florida for the development of the mission modules, and with the Commander, Mine Warfare Command and the Navy Warfare Development Center on an experimentation schedule. ONR/CSS intend to have the first AUV mission package ready when the *SWIFT* is available for experimentation in FY2004. Additional AUV mission packages and the USV mine sweeping mission package will follow. Lessons learned from experimentation would be applied to the LCS, and reduce risk to the definition of MCM mission modules composition. Additionally, these unmanned vehicle mission packages provide a contingency capability for operating forces and provide a readily deployable underwater search and survey capability that could be used for homeland defense.

I. INTRODUCTION

Mine Countermeasures is traditionally a slow operation. This is because: 1) significant time is necessary to bring specialized mine countermeasures ships and equipment into theater, 2) current systems have limited stand-off thus requiring the operation of manned systems (ships, helicopters, and divers) in the minefield and, 3) the time required to eliminate clutter. Fielding of systems organic to the Fleet will begin to enable operating forces to locate, assess, and possibly avoid enemy minefields. Emerging organic neutralization systems will provide a limited capability to neutralize mines; however, these first generation systems represent only a start to solving the mine problem. Science and Technology (S&T) investments in mine warfare are primarily within the Organic MCM Future Naval Capability (FNC) which develops and transitions technologies enabling Seapower 21 and addressing critical gaps in the ability of naval forces to conduct successful Sea Strike, Sea Shield and Sea Basing operations in anti-access (mined) environments. The focus of these efforts includes the development of cooperating, unmanned MCM systems (UUVs, USVs, UAVs). The goal of current and near-term S&T efforts is to reduce tactical timelines and eliminate the need for manned operations in minefields. The development of unmanned MCM systems emphasizes networked, cooperating systems which can be scaled, are easily deployed, and can be tailored to counter specific threats and within distinctive local environments.

The planned acquisition of the HSV-2 *SWIFT* for MCM and Littoral Combat Ship (LCS) experimentation provides a significant opportunity to examine and accelerate cooperating, unmanned systems for mine countermeasures. Networked unmanned vehicles offer the potential to greatly increase the speed and safety of MCM operations. S&T investments are developing containerized mission packages (inexpensive AUVs for minehunting, and Unmanned Surface Vehicle (USV) for minesweeping) for demonstration on *HSV-2 SWIFT*. This builds on the rapid advance of AUV technologies and capabilities demonstrated on *HSV-X1* during Fleet Battle Experiment- JULIET in July 2002. ONR is currently working with the Coastal Systems Station, Panama City, Florida, for development of the mission modules, and with the Commander, Mine Warfare Command and the Navy Warfare Development Center on an experimentation schedule. ONR/CSS intend to have the first AUV mission package ready when *SWIFT* is available for experimentation in FY2004. Additional AUV mission packages and the USV mine sweeping mission package will follow in late FY2004 and FY2005. Lessons learned from experimentation would be applied to the LCS development and reduce risk to the definition of MCM mission package composition. Additionally, these unmanned mission packages provide a contingency capability for operating forces and provide a readily deployable underwater search and survey capability that could be used for homeland defense. Already, during Operation Iraqi Freedom AUVs proved their value in MCM operations during the mine clearance operations carried out in the port are of Um Qasr.

II. MISSION MODULE DESIGN

The Coastal Systems Station has been designated as the chief systems integrator and lead organization responsible for integration of the unmanned vehicle systems onto the HSV-2 *SWIFT*. These modularized mission packages will consist of containerized versions of the Bluefin Robotics, Incorporated Battle-space Preparation Autonomous Underwater Vehicle (BPAUV) shown in Figure 2 and the Remote Environmental Monitoring Units (REMUS) from Hydroid, Incorporated also shown in Figure 2. Follow-

Fig 1. High Speed Vessel

on efforts will include the USV based mine sweeping capability.

Each mission module will be self-contained, transportable, and versatile. Everything necessary for mission planning, vehicle operations, routine maintenance, and post-mission analysis will be contained in each system container. The main requirements placed on these modularized mission packages are ruggedness, versatility, functionality, self-containing, and seamless C4 connectivity. The containers will provide the ruggedness and robustness needed to withstand rigors of shipping to the port of deployment thereby ensuring a working system upon arrival. Electrical and network connections will be of a simple standard connection to readily connect with the host platform. These containers will also be versatile. Once on board the *SWIFT* or other vessels, these mission modules will support maintenance, operations, mission planning, communications, data management, and possibly even post mission analysis (PMA) of data. They will provide the workspace and needed infrastructure for routine at-sea maintenance. While they will not accommodate large catastrophic repairs, they will support day-to-day maintenance issues. Each module will provide an internal C4 workspace necessary for operational mission planning and mission monitoring, and will provide communications connectivity with the host vessel. Lastly, each module will provide the necessary workspace and equipment needed for management and processing of all of the data from the AUV systems including the sonar PMA software. This same PMA software will also be housed in a separate PMA module along with the associated MCM tactical decision aid systems. A notional module/container design adapted from the vendor design for the BPAUV container is shown in Figure 3.

The BPAUV mission module will contain a guide rail system for storing and moving the vehicles in and out of storage, electrical/mechanical workspace, spare parts/tools storage, and x-y overhead lift for moving sections/batteries, battery storage/charging station, and a mission planning/PMA workstation with a MEDAL interface. The REMUS module will be much like the design shown in Figure 4. REMUS vehicles and equipment storage area will replace the guide rail system required for the BPAUV module, and, due to REMUS smaller size and weight, there will be no overhead lift. The basic PMA module will be a smaller design with the necessary C4 connectivity with the AUV modules. It will contain the PMA computers, MEDAL workstation and a small desk workspace.

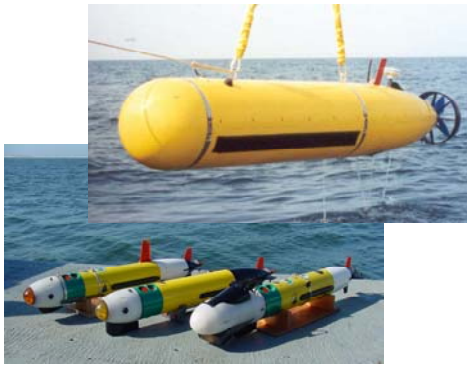

Fig 2. BPAUV (above) & REMUS (below)

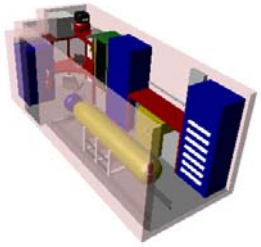

Fig 3. BPAUV Mission Module

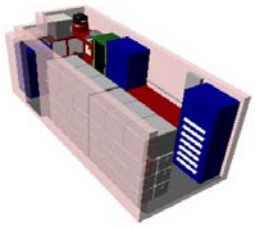

Fig 4. REMUS Mission Module

III. BPAUV DEVELOPMENT FOR MISSION MODULES

Related efforts in sampling the ocean environment have shown that relatively small and inexpensive autonomous undersea vehicles (AUVs) fitted with appropriate sensors can reliably perform a variety of data collection missions. The ONR MCM S&T program has capitalized on these AUV developments, pursuing the development of AUV systems for MCM missions. Recent technology demonstrations have shown that AUVs fitted with available sensors can be employed in MCM missions. These prototypical MCM systems have shown a significant potential for improving organic MCM capabilities through developments in various sensor and vehicle technologies. Bluefin Robotics, Inc. has participated in the advancement of AUV technologies for MCM. Bluefin's BPAUV class of vehicles has been developed and successfully employed

during recent ONR MCM technology demonstrations, integrating various vehicle and sensor technologies to perform single-vehicle MCM mission tasks. In support of ONR's HSV-2 *SWIFT* MCM experimentation program, Bluefin Robotics will further develop its BPAUV class of AUV with the design and development of 4 new systems for integration by CSS into the mission modules. Bluefin will collaborate with CSS to carry out this development, and will develop the AUVs and ancillary support equipment for two MCM mission packages (2 BPAUVs each), and provide the requisite technical support and spares.

IV. REMUS DEVELOPMENT FOR MISSION MODULES

The Woods Hole Oceanographic Institution and Hydroid, Inc., have participated in the advancement of AUV technologies for MCM. Hydroid's REMUS 100 class of vehicles has been developed and successfully employed during ONR MCM technology demonstrations, integrating various vehicle and sensor technologies to perform single-vehicle MCM mission tasks.

ONR has requested the development of two mine counter measure packages based on the REMUS 100 vehicle system. One package will be delivered in early FY 04, and a second package will be delivered later in FY 04. Hydroid, Inc. will deliver the hardware to the CSS. CSS will integrate this hardware into the REMUS mission module developed in cooperation with Hydroid, Inc. The fully integrated system will then be delivered to the *SWIFT* by CSS. Once delivered for MCM experimentation, the AUV packages will be maintained and operated by the mine Warfare Community as they participate in the evaluation of prototypical AUV systems for MCM. For this reason, technical documentation, logistic support, and training packages will be developed to support the demonstration and experimentation with these systems at sea.

The REMUS 100 based AUV MCM packages will be designed and developed to investigate the potential to meet the following requirements:

- Provide the capability to perform technology evaluations in very shallow to shallow water (3-100 m) Search Classify and Map (SCM) MCM missions with an onboard Computer Aided Detection and Computer Aided Classification (CAD/CAC) system and an onboard acoustic communication system;
- Provide the capability to perform technology evaluations in very shallow to shallow water (3-100m) during reacquisition missions with a high resolution sidescan sonar, a forward looking sonar (DIDSON), or an Electronic Still Camera and Strobe systems;
- Provide the capability to evaluate the potential to redirect the mission of the SCM or reacquire vehicles
- Provide the capability to reconfigure the prototype reacquisition vehicle with different payload packages - both DIDSON high resolution forward looking sonar and an electronic still camera and strobe packages will be incorporated as candidate technologies for further investigation and evaluation.
- Provide a bi-directional gateway communication link from the HSV to any of the operating AUV's via a buoy outfitted with acoustic and radio frequency modem links and a GPS receiver for experimentation and evaluation of candidate command and control capabilities;
- Provide the capability to launch and recover the demonstration vehicles and support equipment from Combat Rubber Raiding Craft (CRRC) or Rigid Hull Inflatable Boat (RHIB).

V. UNMANNED SURFACE VEHICLE MINE SWEEPER MISSION MODULE

Unmanned minesweeping has significant tactical advantages over other forms of minesweeping. Unmanned systems take the man out of the loop, and provide a safe and efficient means of neutralizing mine threats without endangering personnel. ONR has initiated a modular mission package program for a USV-based minesweeping system. The program is scheduled to begin late in FY2003 for delivery and experimentation in FY2005.

The envisioned USV Mine countermeasures Minesweeping mission module for experimentation aboard *SWIFT* will be based on a remotely operated, Navy-standard 11 meter RHIB installation. The system to be developed consists of an open-loop electrode sweep system, powered by microturbine technology. Conventional open loop tails feature low drag and high output performance for magnetic influence sweeping. Under the open loop concept for the USV, two cable electrodes would be towed from the boat transom, with one cable electrode connected to the end of an insulated sweep cable to create electrode separation in the seawater medium. A DC current applied to one electrode returns to the second electrode via an "open loop" path through the seawater, thereby creating the magnetic sweep field. For acoustic sweeping, a Mini Mk-104 device will be incorporated into the sweep system. Activated by water flow induced cavitations, the acoustic device requires no electrical power and would be streamed from the aft end of the aft-most electrode of the magnetic tail system.

Acknowledgments

The ONR MCM mission module development program has been guided by Dr. Douglas Todoroff, Acting Director, Sensing and Systems Division, Ocean Atmosphere & Space S&T Department. Dr. Sam Taylor of the Coastal Systems Station is the program manager and driving force for integration of the AUV systems and the development of the mission module containers.